An optical clock based on a single trapped $^{88}Sr^{+}$ ion

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The reference transition for the $^{88}Sr^{+}$ single ion optical clock is the 5s $^{2}S_{1/2}$ – 4d $^{2}D_{5/2}$ electric quadrupole transition at 445 THz. Following the development of femtosecond optical frequency combs, rapid reductions in the uncertainty of the standard were achieved, leading to a frequency measurement with an uncertainty of 1.7 Hz (3.8 parts in 10^{15}) [1] and adoption of the standard as a secondary representation of the second.

To optimize the performance of the $^{88}Sr^{+}$ optical frequency standard so that its stability is close to the quantum projection noise limit set by the 0.4 s lifetime of the 4d $^{2}D_{5/2}$ level, the 674 nm probe laser linewidth must be reduced to the sub-hertz level for timescales of a few seconds. Probe laser improvements have resulted in a linewidth of 1.4 Hz on a timescale of 3 s, broadening to 4 Hz at 30 s, and a minimum frequency instability of 2.5×10^{-15} at 1 s [2], measured by monitoring the beat frequency between two similar systems. When one of these lasers is used to interrogate the clock transition in $^{88}Sr^{+}$, a Fourier-transform limited linewidth of 9 Hz is observed [2]. Further improvements are expected by using longer interrogation times and with the introduction of reference cavities designed to have a reduced sensitivity to acceleration [3].

The frequency stability and reproducibility of the $^{88}Sr^{+}$ standard is being assessed by comparisons between two similar standards. To date, a relative frequency stability of 3×10^{-15} over a 100 s averaging time has been observed, with further reductions expected to result from the probe laser improvements described above and improvements to the stability of the magnetic field within the trap. To optimise the parameters of the probe laser lock to the clock transition, a model of the servo system has also been developed. Improved stability will enable detailed studies of systematic frequency shifts of the clock transition frequency to be carried out, targeting relative stabilities and reproducibilities at the 10^{-17} level. Ultra-stable microwave frequencies can be derived from the optical standard using a femtosecond optical frequency comb, and the factors limiting the fidelity of the downconversion process are currently being studied.

With these improvements, a new measurement of the clock transition frequency will be limited by the uncertainty of the NPL caesium fountain primary frequency standard. When combined with the 2004 measurement and frequency measurements of other optical standards around the world, this will lead to tighter constraints on the time variation of fundamental physical constants, in particular the electron to proton mass ratio m_e/m_p.

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